RENEWABLE ENERGY

REPORT LIBRARY

SOLAR DOMESTIC HOT WATER SYSTEM

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

SOLAR DOMESTIC HOT WATER SYSTEM

Prepared by

Marcus McBeen
P.O. Box 64
Gardiner, MT 59030

August, 1981

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
Grant Agreement Number 060-811

Available from

Montana State Library, 1515 East Sixth Avenue
Justice and State Library Building, Helena, Montana 59620

I. Program Objectives

Although a large number of Solar DHW heating systems are now available, the economic justification for consumer purchase of these systems is questionable. Tests conducted by the New England Electric Co. on 100 installed systems indicate an average energy savings of only 41%. The average "net ownership" costs of these systems is $138.00 per year more than the normal gas or electric DHW heating system would cost them. Joan T. Bok, Vice President, New England Electric, states "The initial cost of a solar water heating system remains high. If solar water heating is to gain widespread use among customers in the Northeast in the near term, the industry must find ways to significantly reduce the costs." Most demonstration projects to date parallel the finds of New England Electric. In spite of manufacturers' claims of 70 to 80% energy savings and short pay back periods, an economically justified solar DHW heating system is not readily available for use in the northern section of the United States. Some of the problems with present systems are as follows:

1. High collector costs--$10.00 to $20.00 per sq. ft.
2. Small thermal storage--80 to 120 gallons, while a family uses 70 gallons a day. This does not allow for adequate thermal storage for cloudy days.
3. High overall system costs--Retail installed costs for a system providing 40 to 50% of the DHW requirements in the Northern U.S. range from $2,000.00 to $4,000.00 before tax credits are deducted.
4. Installation difficulties due to improper orientation of house, angle of roof, lack of space for storage tank and plumbing problems.
5. High cost of site installation.
6. Poor appearance of installation, due to placement of collectors on roof oriented at improper angle and orientation.

Our goals for this project are:

1. Establish or find a manufacturing source for a high quality collector with the following characteristics:

   a. cost of less than $7.00 per square foot
   b. design life of 20 years
   c. warrenty of 3 to 5 years
   d. good efficiency at Δ_t of 120°F, to operate during Montana winters

2. Two to three days of thermal storage capacity
3. Immunity from freezing conditions
4. Reliable operation
5. Modular factory assemble of total system
6. 85% energy savings for total installed system
7. Payback of 11 years.

8. Architect designed structure to hold system that will look good.
9. Low installation costs.
10. Demonstration of an economically justified, good looking solar domestic hot water heating system.

II. Project Implementation:

The general design of the system followed the proposal in most areas. The structure of the solar DHW system was designed by Doug Rand, Architect, Bozeman, Montana, and the structure proved easy to build and assemble. The storage tank was placed under ground to facilitate drain back of water from the collectors to the tank. Eighteen inches of fiberglass insulation was used around the sides and top of the tank and six inches of styrofoam under the 300 gallon tank.

A block diagram of the drain back Solar DHW system used is attached as exhibit #1. Pictures of the completed system are attached as exhibit #2.

1. Project Planning and Acquisition:

Most planning for the project was accomplished during the proposal preparation. Mr. Doug Rand dèsigned the support structure for the system as well as the collector housing. No problems were experienced in obtaining the materials and parts used in the system. Suppliers of parts and materials were:

Terra Light	Absorber Plates
Olympic Solar	Plating
C.E. Glass	Glass
Pacific H. & F.	Sheet Metal
McKlees	Metal Fab.
Macon Supply	Silicone Caulk
Cadilac Plastic	Teflon
Simkins and Hallin	Lumber
Mountain Supply	Pipe and Fittings.
Heliotrope Gen.	Differential Control
Gaco Western	Rubber Coating
Richdel	Pump and Vaccum Breaker

2. System Installation:

Approximately 100 hours were expended in the installation of this Solar DHW system. Most of this time (over 50 hours) was spent building the structure to hold the collectors and storage tank. No major problems were encountered during the installation and the finished structure looks good and performs well. A brief description of each part of the system is as follows:

A. Collector Absorber Plates: Plates made by Terra Light

were selected due to price, performance and delivery. Chrome plating these collectors raised the cost to about $7.74 per square foot. (See EXHIBIT # 3 for Data Sheet)

B. Collector Housing: A sheet metal housing was used and was found to be adequate. However, again the cost of about $400,00 was considered to be too high. Wood was considered, but was not used due to shorter life, more maintenance, and probable outgassing at stagnation temperatures. Other materials were considered including extruded aluminum (costs were too high), fiberglass (looks good but delivery time was excessive). Fiberglass reinforced concrete looks like a very good and economical possibility and will be tried on a future collector.

C. Storage Tank: The 300 gallon tank was designed using pressure treated plywood and a GAco rubber liner. The cost of the tank is low but labor was high. A high temperature fiberglass tank would probably be a more economical choice if labor costs are considered.

D. Storage Tank Insulation:: Eighteen inches of fiberglass insullation was used around and on top of the storage tank. The cost of the material is low and insulation properties are good. However, an outer box must be used to protect the insulation thus raising the cost, and the insulation can get wet if there is a leak. Approximately 10 inches of urathane insulation could be used without an outer cover, and since labor costs would be reduced the overall costs might be less. In any case, the size of the overall tank could be reduced by about 16 inches which would reduce size and excavation costs.

E. Pipe Insulation: Two pieces of 6"x12" styrofoam insulation were used to sandwich the pipes going to and from the Solar DHW System. Groves were cut in one piece of the insulation to accomodate the pipes, and visqueen was wrapped around the styrofoam to protect it from water. This method of insulation was economical and very effective. The heat loss from the pipe run is very low as indicated by the heat exchanger test.

F. Collector Support Structure: The support structure looks good and is functional. However, the costs of material and labor are high. Significant reductions in cost are possible in this area, and a simpler structure with less material could be used.

G. Installation: Backhoe work, plumbing and electrical went well. Underground wiring was used and layed in the trench used for the water pipe.

Date	Time	Tank Temp. Top	Tank Temp. Bottom	
29 May 81	7 PM	155.5	148.5	
30 May 81	8AM	141.4	128.0	
30 May 81	7PM	135.0	110.6	
31 May 81	7 PM	105.0	82.5	Cloudy
2 June 81	7 PM	119.5	109.1	Cloudy
6 June 81	7 PM	144.1	134.0	
25 June 81	7 PM	164.0	152.3	
July		140 to 180 throughout month		
28 July 81	7 PM	172	158.0	
3 Aug 81	7 PM	168	154.0	
4 Aug 81	7 PM	158.7	149.8	Cloudy

Note; The efficiency has reached 76% on clear warm days.

Heat Exchanger tests;

Date	Tank Top	Tank Bot.	T_{in}	T_{out}	
6/10/81	119.2	110	52	118	Cloudy Day
6/11/81	124	106	52	121	Cloudy Day

5. System cost; Due to the necessity of purchasing more material than required for One unit, the costs were higher than the proposal first unit costs. A number of hardware changes were made and some material and parts purchased were not used. As an example, asub-mersable pump was initially tried, but was found to be unsatisfactory due to its short life, when operating above 140°. As a result, the actual cost of material and labor for the Solar DHW system was $2,675.11 more than that estimated in the proposal. A large part of this extra cost was for extra material which can be used on later systems. (See EXHIBIT # 4 for a cost breakdoun).

6. Economic Evaluation; Since this first unit was an engineering prototype system, it is not appropriate or meaningful to figure payback time of the total cost of the project which was $7,782.11. (See Exhibit #4 for proposal cost verses actual cost tabulation). The last column of Exhibit #4, unit cost, tabulates the cost which would apply to the next unit built to the same design. This unit cost of $2,873.66 (not including G & A fee) compares very favorably with the $2,672.00 cost of the proposal for the second and third units. The second and third unit cost will be further reduced from the unit cost figures of exhibit 4 by using a cheaper collector housing, a simpler support structure, and a styrofoam or urethane foam insulated tank. The installation costs were low and no major changes would be made for the next units. Labor and material costs for the next several units are estimated to be $2,200.00 and labor and material unit cost for 100 systems should be around $1,900.00. With a 30% G & A plus fee the cost comes to $2,860.00 for several units, and $2,470.00 for 100 units. Exhibit #5 contains TI-59 calculator print out data on system performance and cost and payback data on the $2,860.00 cost and the $2,470.00 cost. As you can see the payback looks good.

3. System Testing and Modification: The system has been tested using the Heliotrope Digital Temperature readouts, a Blue White Ind. Flowmeter and a Leads and Northrup temperature potentiometer. The water flow through the collectors was set to 3.5 GPM and has remained set at this point. The efficiency of the 120' coper heat exchanger was checked at 5 GPM using an L & N temperature potentometer. The results were as follows:

Temperature in	52°F
Water tank temperature (top of tank)	124°F
Water tank temperature (bottom of tank)	106°F
Water temperature of output from heat exchanger	121°F

Problems observed during testing:

a. The vacuum breaker leaked. Richel was called and they advised me to clean the breaker. This corrected the problem.

b. A leak developed in one of the tank feedthru fittings. The tank was drained and the leak repaired.

The peak efficiency of the system was measured at 65% to 76%. With a use rate of 46,648 BTUs/day (70 gal x 8.33 x 80°F Temp. Rise) the system has been supplying 100% of our hot water during the summer months. From 17,000 to 19,616 BTUs/hr. are stored around 1 to 3 PM. The temperature of the 300 gallon tank is raised from 20 to 30 degrees on a clear day (50,000 to 75,000 BTUs), and frequently is shut off by the high temperature storage cut off at 180°F. The storage tank temperature normally runs from 130°F to 180°F depending on the amount of cloud cover.

4. System Performance: Since no mechanized test equipment was available, the performance was only checked periodically. However, 100% of our hot water has been obtained from this system since May, 1981.

Date	Time	Col. Temp.	T_1	T_o	Temp. Rise	Water Flow
25 Jun 81	3:30 pm	180.5	160.9	170.4	9.5	3.56 GPM
	3:40 pm	180.8	161.2	170.8	9.6	"
	4:00 pm	-	160.9	170.8	9.9	"

17,318 BTU/Hr - Collector size = 86.1 SF
Tank Size = 300 Gal.
Insulation = 290 BTU/SF

86.1 SF x 290 BTU/SF = 24,969 BTU/Hr

Efficiency = 17,318 BTU ÷ 24,969 BTU = 69.4%

III. Conclusions and Recommendations:

The drainback DHW system constructed has been very efficient and reliable. The collector costs of about $10.00/sf was above that anticipated, and the cost of the structure ($2,400.00) was also higher than expected. If the collector costs can be reduced to $7.00/sf ($602.70) and the support structure can be reduced to several hundred dollars, the system would have immediate commercial merit.

IV. Monitoring:

The system performance will be periodically monitored and performance data will be made available upon request.

V. Public Availability:

Approximately thirty people have seen the system, most of which have been from Gardiner. The responses have been very favorable. The system is available for review at any reasonable time.

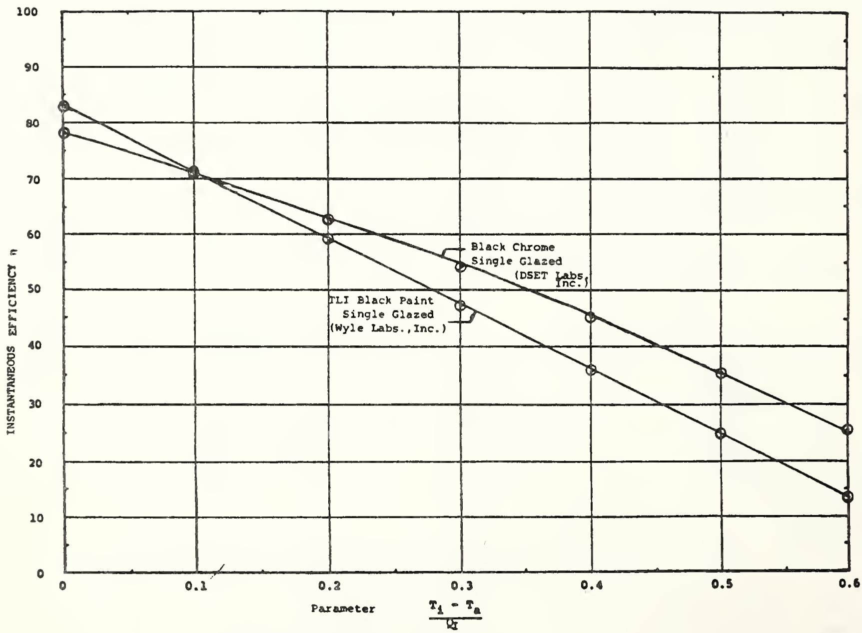
VI. Program Evaluation:

I think the program is excellent. All personnel have been very helpful and timely in their response. I am hopeful that commercial development aspects of alternate energy can be expanded.

FLOW RATES AND PRESSURE DROPS

Flow Rate (GPM)	Pressure Drop (psi) Model C-75	CT-75
0.25	0.001	0.006
0.50	0.005	0.023
0.75	0.010	0.050
1.00	0.018	0.086
1.50	0.040	0.183

INSTANTANEOUS EFFICIENCY GRAPH
(Based on Absorber Area)



TERRA-LIGHT, INC., 30 MANNING ROAD, P.O. BOX 493, BILLERICA, MASS. 01821, TEL. (617) 663-2075

A wholly owned subsidiary of Butler Manufacturing Company.

EXHIBIT #3

BUDGET

	Grant Est.	Actual Exp.	Invoice	Company	Diff.	Unit Cost
1. Salaries						
Design Time	None	--	--	--	--	--
2. Operating Expense						
A. Contracted Services						
1) Structure Design	$1,500.00	$1,500.00	--	d. Rand	--	0
2) Site Preparation						
Electrical	60.00	60.00	Cash	--	--	60.00
Plumbing	90.00	150.00	Cash	D Holland	+ 60.00	150.00
Backhoe Work	64.00	128.00	Cash	K Holland	+ 64.00	128.00
Landscaping	30,00	0	--	--	(30.00)	-------
Piers	36.00	0	--	--	(36.00)	-------
3) Structure Fabrication	484.00	815.00	2$3/81	Crev. C.	+331.00	300.00
4) Storage Tank Fab.	48.00	--	--	--	(48.00)	50.00
Totals	$2,312.00	$2,653.00			+341.00	$688.00
B. Supplies and Material						
1) Site Preparation						
a. 1 yard concrete	$70.00	0	--	--	(70.00)	--
b. Wire, connectore etc.	30.00	149.40	24640 668742	CED Grainger	+119.40	40.00
c. 120' 3/4" Pipe and Misc	120.00	168.20	26425	Mount Sup.	+48.20	120.00
d. Anchor Bolts and misc	30.00	4.28	2/15/18	Shop Cen	(25.72)	20.00
e. Urathane ins.	50.00	149.76	14261	Sim/Hal	+99.76	100.00
f. Sod and Grass seed	40.00	0	--	--	(40.00)	--
g. Pier forms	10.00	0	--	--	(10.00)	--
	$					
Totals	$350.00	$471.64			+$121.64	$280.00

EXHIBIT #4

	Grant Est.	Actual Exp	Invoice	Company	Diff.	Unit Cost.
C. Communications						
Telephone	30.00	300.00est.	--	Bell	+270.00	--
Reports and postage	15.00	15.00est.	--	--	0	--
D. Travel	--					
E. Rent	--					
3. Equipment						
Watt meter	--					
Water Meter	100.00	52.81	70501	Blue/White	(47.19)	--
Temp.meter and rec.	--					
Electronic therm.	90.00	0	--	--	(90.00)	--
4. Administration 10%	430.70	430.70	--	--	0	--
					+132.81	0
Total costs	$4,837.70	$7,782 .11			$2,945.11	$2,873.66

EXHIBIT # 4

2. Structure for system	Grant Est.	Actual Exp.	Invoice	Company	Diff	Unit cost
a. 3 Absorber panels	$450.00	$752.40	18616	Terra L.	+302.40	$421.35
b. 3 Glass cover plates	170.00	221.36	13753	C E Glass	+ 51.36	165.75
c. 100 SF Teflon	50.00	41.40	--	Cad Plast.	(8.60)	41.40
d. Misc. Screws and strips	30.00	10.00	Cash	Grainger	(20.00)	10.00
e. Silicone caulking	15.00	18.23	30077	Macon	+ 3.23	7.29
f. Lumber nails etc.	400.00	663.00	15642,13752 14370,11659	Sim./Hal.	+263.00	400.00
g. Giberglass ins. 6"	85.00	188.16	13098	Sim/Hal.	+103.16	100.00
h. Control unit	70.00	129.50	24303	Heliotrope	+ 59.50	70.00
i. Pump	70.00	62.20	664907	Grainger	(7.80)	62.20
j. Heat Exchanger	100.00	197.40	26548,26549	Mount. Sup.	+ 97.40	100.00
k. Misc. Valves and pipe	50.00	50.00	--	D. Holland	0	50.00
l. Pipe Insulation	20.00	0	--	--	(20.00)	--
Additional Material used that was not in the proposal/Grant.						
m. Vacume Breaker	0	11.25	36979	Richdel	+ 11.25	11.25
n. Glass Ship.	0	78.08	10085	Deyoung	+ 78.08	60.00
o. Plat. of Abs.	0	327.18	21 Jan 81	Olimpic	+327.18	--
p. Abs. Ship.	0	114.96	10252,04798	Deyoung	+114.96	--
q. Coll. Housing	0	350.00	4/20/81	McLees	+350.00	150.00
r. Housing Back	0	42.26	64764	Pacific	+ 46.26	--
s. High Tenp Ins.	0	84.87	10147	Deyoung	+ 84.87	10.00
t. Gaco Rubber	0	151.69	3678,6512	Gaco	+151.69	72.00
u. Bander Rent	0	57.80	45449	Rental shop	+ 57.80	--
v. Richdel Pump	0	54.41	36979	Richdel	+ 54.41	--
w. Coll Ship.	0	76.27	10316	Deyoung	+ 76.27	50.00
x. Hardware and Paint	0	43.25	11885	Shop cen	+ 43.25	30.00
y. Pipe and Misc.	0	3.06	421364	Petrolane	+ 3.06	10.00
" "	0	5.88	421387	"	+ 5.88	
" "	0	9.08	2/2/81,3/17/81	Shop Cen	+ 9,08	
z. Sty. Ins.	0	49.92	14261	Sim/Hal.	+ 49.92	49.92
aa. Pipe and Misc.	0	47.55	23 May 81	C of C	+ 47.55	20.00
ab. Visqueen	0	24.50	--	Sim/Hal	+ 14.50	14.50
	$1,510.00	$3,859.66			+$2,349.66	$1,905.66

EXHIBIT # 4

F-Chart (page 1)

Monthly Energy Load supplied by Solar

Program No: ST 36/e **Calculation No:**

Calculated on: 9 Aug. 1981 Solar DHW System

Month		1.00	4.00	7.00	10.00
Total load	Btu-kJ/mo.	1506730.40	1506730.40	1506730.40	1506730.40
Collector area	m^2	86.10	86.10	86.10	86.10
Supp. by solar	kJ/mo.	1019146.06	1336532.69	1655042.06	1522644.24
Solar faction	%	0.68	0.89	1.00	1.00
	ft^2-m^2				
	Btu-kJ/mo.				
	%				
	ft^2-m^2				
	Btu-kJ/mo.				
	%				
	ft^2-m^2				
	Btu-kJ/mo.				
	%				

Month		2.00	5.00	8.00	11.00
Total load	Btu-kJ/mo.	1506730.40	1506730.40	1506730.40	1506730.40
	ft^2-m^2	86.10	86.10	86.10	86.10
	Btu-kJ/mo.	1042902.07	1484217.23	1673896.07	1200053.76
	%	0.69	0.99	1.00	0.80
	ft^2-m^2				
	Btu-kJ/mo.				
	%				
	ft^2-m^2				
	Btu-kJ/mo.				
	%				
	ft^2-m^2				
	Btu-kJ/mo.				
	%				

Month		3.00	6.00	9.00	12.00
Total load	Btu-kJ/mo.	1506730.40	1506730.40	1506730.40	1506730.40
	ft^2-m^2	86.10	86.10	86.10	86.10
	Btu-kJ/mo.	1415191.23	1663462.76	1605265.49	772643.82
	%	0.94	1.00	1.00	0.51
	ft^2-m^2				
	Btu-kJ/mo.				
	%				
	ft^2-m^2				
	Btu-kJ/mo.				
	%				
	ft^2-m^2				
	Btu-kJ/mo.				
	%				

EXHIBIT # 5

KOLLWITZWEG 19
61 DARMSTADT - ARHEILGEN
WEST GERMANY

SOLARCON

607 CHURCH
ANN ARBOR, MICHIGAN 48104
U.S.A.

F-Chart (page 2)

Yearly energy load supplied by solar
Economical analysis

Program No: ST 36/e

Calculation No:

Calculated on: 9 Aug. 1981 Solar DHW System

Collector area	A	$(ft^2)-(m^2)$	86.10	
Yearly fraction supplied by solar		(%)	0.87	
		$(ft^2)-(m^2)$		
		(%)		
		$(ft^2)-(m^2)$		
		(%)		
		$(ft^2)-(m^2)$		
		(%)		

$2,470.00, 40% Cr.

~~m~~² - ft²	86.10
$/10⁶~~kJ~~ - Btu	10.00
$	-49.47
$/10⁶~~kJ~~ - Btu	20.00
$	108.58
$/10⁶~~kJ~~ - Btu	30.00
$	266.62
$/10⁶~~kJ~~ - Btu	40.00
$	424.66

m² - ft²	
$/10⁶kJ - Btu	
$	
$/10⁶kJ - Btu	
$	
$/10⁶kJ - Btu	
$	
$/10⁶kJ - Btu	
$	

$2860.00, 40% Cr.

Collecter area	86.10	~~m~~² - ft²
Fuel cost	10.00	$/10⁶~~kJ~~ - Btu
Yearly savings	-82.28	$
Fuel cost	20.00	$/10⁶~~kJ~~ - Btu
Yearly savings	75.76	$
Fuel cost	30.00	$/10⁶~~kJ~~ - Btu
Yearly savings	233.80	$
Fuel cost	40.00	$/10⁶~~kJ~~ - Btu
Yearly savings	391.85	$

m² - ft²	
$/10⁶kJ - Btu	
$	
$/10⁶kJ - Btu	
$	
$/10⁶kJ - Btu	
$	
$/10⁶kJ - Btu	
$	

EXHIBIT # 5

KOLLWITZWEG 19
61 DARMSTADT - ARHEILGEN
WEST GERMANY
TEL: 06151/31887

SOLARCON

607 CHURCH
ANN ARBOR, MICHIGAN 48104
U.S.A.
TEL: 313/769-6588

Memories

Program No. - ST 36 /e

Calculation No:

Calculated on: 9 Aug. 1981 Data for $2470.00 System

Location:

No.	Description	Unit (SI)	Value	Unit (E)
00			0.	
01			30.	
02			12.	
03			0.	
04			0.	
05			15804338.85	
06			207.5116215	
07			0.	
08			30.1	
09			1506730.4	
10	Total load per year	kJ/year	18080764.8	Btu/year
11	Energy collected: 1st collector size	kJ/year	15804338.85	Btu/year
12	2nd collector size	kJ/year	0.	Btu/year
13	3rd collector size	kJ/year	0.	Btu/year
14	4th collector size	kJ/year	0.	Btu/year
15			0.	
16			0.	
17			50.	
18		Jan	305247.2891	
19		Feb	308285.2323	
20		March	441334.2338	
21	Total insolation on tilted	April	391436.1561	
22	surface HT	May	438524.0912	
23		June	513592.0396	
24	~~ambient temperature~~	July	488682.0086	
25		Aug	502664.0132	
26	~~heating degree hours~~	Sept	486574.0581	
27		Oct	463486.1171	
28		Nov.	352354.2093	
29		Dec	228301.2525	
30	Storage fluid capacitance/ Ac Cst/Ac	W/°C, m^2	100.	Btu/h, °F, ft^2
31	Collector fluid capacitance Cc/Ac	W/m^2, °C	20.32	Btu/ft^2, h, °F
32	Storage size correction factor K2		0.852481414	
33	Load heat exchanger correction factor K4		1.	
34	Storage tank size M	Liter/m^2	3.484	gal/ft^2
35	Cost of storage tank	$/liter	1.599	$/gal.
36	Fixed installation costs	$	477.36	$
37	Installed costs (proportional)	$/$m^2$	6.1	$/$ft^2$
38	Interest charge		0.14	
39	Auxiliary fuel costs	$/mill kJ	10.	$/mill Btu
40	FR x $\tau\alpha$		0.6825	
41	FR x UL	W/m^2, °C	0.6	Btu/ft^2, h, °F
42	Space heating load factor Ua	W/°C	0.	Btu/°F.h
43	Water heating load per month Qw	kJ/month	1506730.4	Btu/month
44	Domestic warm water correction factor K3		.9921275426	
45	Effectiveness of storage heat exchanger εc		1.	
46	FR'/FR		1.	
47	Minimum warm water temperature Tw	°C	120.	°F
48	Public water supply temperature Tm	°C	45.	°F
49	Collector Area Ac	m^2	86.1	ft^2

EXHIBIT # 5

Memories

Program No. ST 36 /e

Calculated on: 9 Aug. 1981, Data for 2860.00 System.

Calculation No:

Location:

		(SI)		(E)
00			0.	
01			0.	
02			0.	
03			0.	
04			0.	
05			0.	
06			0.	
07			0.	
08			0.	
09			0.	
10	Total load per year	kJ/year	0.	Btu/year
11	Energy collected: 1st collector size	kJ/year	0.	Btu/year
12	2nd collector size	kJ/year	0.	Btu/year
13	3rd collector size	kJ/year	0.	Btu/year
14	4th collector size	kJ/year	0.	Btu/year
15			0.	
16			0.	
17			0.	
18		Jan	305247.2891	
19		Feb	308285.2323	
20		March	441334.2338	
21	Total insolation on tilted	April	391436.1561	
22	surface HT	May	438524.0912	
23		June	513592.0396	
24	~~ambient temperature~~	July	488682.0086	
25		Aug	502664.0132	
26	~~heating degree hours~~	Sept	486574.0581	
27		Oct	463486.1171	
28		Nov	352354.2093	
29		Dec	228301.2525	
30	Storage fluid capacitance/ Ac Cst/Ac	$W/{}^oC,m^2$	100.	$Btu/h,{}^oF,ft^2$
31	Collector fluid capacitance Cc/Ac	$W/m^2,{}^oC$	20.32	$Btu/ft^2,h,{}^oF$
32	Storage size correction factor K2		0.	
33	Load heat exchanger correction factor K4		1.	
34	Storage tank size M	$Liter/m^2$	3.484	gal/ft^2
35	Cost of storage tank	$/liter	2.54	$/gal.
36	Fixed installation costs	$	1059.	$
37	Installed costs (proportional)	$\$/m^2$	12.08	$\$/ft^2$
38	Interest charge		0.14	
39	Auxiliary fuel costs	$/mill kJ	10.	$/mill Btu
40	FR x [illegible]		0.6825	
41	FR x UL	$W/m^2,{}^oC$	0.6	$Btu/ft^2,h,{}^oF$
42	Space heating load factor Ua	$W/{}^oC$	0.	$Btu/{}^oF,h$
43	Water heating load per month Qw	kJ/month	1506730.4	Btu/month
44	Domestic warm water correction factor K3		0.	
45	Effectiveness of storage heat exchanger εc		1.	
46	FR'/FR		1.	
47	Minimum warm water temperature Tw	^oC	120.	^oF
48	Public water supply temperature Tm	^oC	45.	^oF
49	Collector Area Ac	m^2	86.1	ft^2

EXHIBIT # 5

15 copies of this public document were published at an estimated cost of $3.00 per copy, for a total cost of $45.00, which includes $45.00 for printing and $.00 for distribution.